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In-situ remediation of TCE by ERD in clay tills. Feasibility and performance of full-scale application insights gained through an integrated investigative approach for 2 sites.

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Background/Objectives. Remediation of trichloroethene (TCE) in clay and other low permeability geologic media, where groundwater flow occurs preferentially in higher permeability sand lenses or fractures, is a significant challenge. At older sites, much of the contaminant mass is present as a sorbed phase in the matrix due to matrix diffusion. The principal challenge for in situ remediation in clay is to achieve effective contact between contaminant and bioremediation additives (e.g., organic electron donors and bioaugmentation cultures). The feasibility and performance of full-scale applications of ERD in clay tills were investigated in a research project including 2 sites in Denmark undergoing remediation since 2006.
Site remediation approach. At the Sortebrovej site an emulsified oil donor (EOS) and a bioaugmentation culture (KB1®) with specific degraders *Dehalococcoides* were injected in a network of screened wells and spread in natural sand stringers embedded in the clay till. At the Gl. Kongevej site organic molasses donor and Bioclear Dechlorinating bioaugmentation culture with specific degraders *Dehalococcoides* were injected with a drive-point probe (Geoprobe) at 25 cm spaced vertical intervals in the clay till in a closely spaced network.
Investigative activities. An integrated investigative approach consisting of water and clay core sample analysis, including stable isotopes and specific degraders, as well as analysis for chlorinated solvents, degradation products, donor fermentation products and redox sensitive parameters combined with modelling was applied. Groundwater monitoring of selected wells was performed 2-3 times per year, and very detailed subsampling (on 0.25-5 cm scale) of the intact clay cores for matrix profile analysis was performed after 2 and 4 years. The transport including matrix diffusion and degradation in fractures/sand stringers and in bioactive zones in the clay till adjacent to the fractures/sand stringers was modelled to gain insight on the effects of sand stringer/fracture /injection spacing, thickness of bioactive zones, density/numbers of specific degraders, donor longevity, etc., on remediation efficiency and timeframes.
Results/Lessons learned. The results showed that the chlorinated solvent TCE was converted into its daughter products (DCE, VC and ethene) but complete conversion of contaminants to ethene (as expected) was not achieved in 4 years. Large variation in the effect of ERD in the clay matrix between sites, boreholes and even between cores was observed. After 4 years, the mass removal at the 2 sites varied between <5% and 50% within the treated zones. The limited efficiency of the bioremediation in terms of mass removal is due to the limited spatial extent of dechlorination. If degradation is restricted to narrow bioactive zones of a few cm developing around fractures and sand stringers, contaminants in the remaining part of the matrix are not degraded and remediation efficiency is low due to the mass transfer limitations. However, the bioactive zones may expand in zones where both donor and chlorinated compounds are present. And in some cores TCE was depleted (degraded to DCE) in zones up to 1.8 m thick, an extent, which could not be explained by diffusive loss to narrow bioactive zones. Hence, biomass migration in the clay matrix appears to play an important role in terms of contaminants mass reduction.